Future Opportunities in Low Energy Electromagnetic Nuclear Physics

Hadronic physics using low energy electromagnetic probes has become an important area of nuclear physics over the last five years. This is principally due to a new generation of experimental capabilities and also to very significant advances in theoretical physics. At MIT-Bates, high duty-factor, polarized electron beams with energies up to 1 GeV are in use with a suite of three innovative detectors. At LEGS-BNL a new polarized HD target is under development for use with polarized photon beams up to 0.5 GeV. At TUNL, a new facility, HIGS, will provide high intensity polarized photons up to 0.2 GeV. Further, development of powerful QCD-motivated effective field theories, e.g. Chiral Perturbation Theory, as well as major advances in *ab initio* calculations of the structure of light nuclei using Monte-Carlo techniques, have motivated new experimental programs focused on fundamental questions at low energies. Many of these involve the nucleon's pion cloud. Both the cloud and the spin effects generated by its orbital angular momentum are inherently properties of extended objects that can only be probed by experiments at low energies. Some of the important scientific questions addressed by low energy electromagnetic facilities include:

Low Energy QCD

- What is the shape of the nucleon and its low-lying excited states?
- What are the charge and electroweak structures of the nucleon?
- What are the spin polarizabilities and sum rules for the nucleon and the deuteron?
- What are the electric and magnetic polarizabilities of the neutron and the pion?
- Can we deduce the pion-nucleon interaction from QCD including dynamic isospin breaking due to the up-down quark mass difference?
- Can we understand the role of the nucleon's pion cloud and underlying QCD symmetries in the sensitive region of threshold photo-pion production?
- Can we understand the chiral structure of the nucleon, including its axial radius and the pi-N sigma term?

Structure of Light Nuclei

- How is the spin of the deuterium and He-3 nuclei distributed among its constituents?
- Can we understand spin-dependent photodisintegration studies of the light nuclei in terms of *ab initio* calculations of these nuclear systems?

Astrophysical Reactions

- What is the neutron-proton capture rate at stellar energies?
- Can we understand the abundance of oxygen in the universe?

Given the importance of these scientific questions to nuclear physics, the large capital investment which has been made in these facilities, and the proven ability to educate and train outstanding young people at MIT, BNL and Duke, **it is essential that the low energy electromagnetic nuclear physics facilities at MIT-Bates, BNL/LEGS and TUNL/HIGS be funded in the base program at a level necessary to exploit their outstanding scientific opportunities**.